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Effect of Display Size on Utilization of Traffic Situation Display for Self-Spacing Task

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SUMMARY

A study was undertaken to investigate applications of Cockpit Display of Traffic Information (CDTI) in the operation of current, conventionally equipped transport aircraft. Since flight decks of the current transport-aircraft fleet probably will not be reconfigured to accommodate a special display dedicated to this purpose, the weather-radar cathode-ray tube (CRT) is the prime contender for the presentation of CDTI. However, unique problems may result from the use of the weather-radar CRT for CDTI, since the CRT size is not optimized for CDTI applications and the CRT is not in the pilot's primary visual scan area.

The primary objective of this study was to assess the impact of display size on the ability of pilots to utilize the traffic information to maintain a specified spacing interval behind a lead aircraft during an approach task. The five display sizes considered are representative of the display hardware configurations of airborne weather-radar systems. A total of 80 simulated approaches were flown during this evaluation and, through the use of pilot questionnaires and performance data, the following results were obtained. From a pilot's subjective workload viewpoint, even the smallest display size was usable for performing the self-spacing task. From a performance viewpoint, the mean spacing values, which are indicative of how well the pilots were able to perform the task, exhibit the same trends, irrespective of display size; however, the standard deviation of the spacing intervals decreased (performance improves) as the display size increased. Display size, therefore, does have a significant effect on pilot performance.

INTRODUCTION

The Federal Aviation Administration (FAA) and the National Aeronautics and Space Administration (NASA) have undertaken a program to explore the conceptual implementation and application aspects of the Cockpit Display of Traffic Information (CDTI) through partial and full workload system studies. As a part of this program, the NASA Langley Research Center is investigating CDTI applications in the operation of current, conventionally equipped, transport aircraft. For this type of aircraft, the prime contender for the presentation of the traffic information is the weather-radar cathode-ray tube (CRT). (See fig. 1.) In contrast to advanced aircraft concepts wherein the traffic information will probably be presented on an electronic horizontal situation display, unique problems may result from the use of the weather-radar CRT for CDTI. The weather-radar CRT size is not optimized for CDTI applications and the CRT is not in the pilot's primary visual scan area.

The primary objective of this study was to assess the impact of display size (the physical viewing area of a CDTI) on pilot ability to interpret and utilize the traffic information to maintain a specified spacing interval behind a lead aircraft during an approach task. The five display sizes considered

ranged from 7.62-cm (3-in.) high by 10.16-cm (4-in.) wide to a 16.51-cm (6.5-in.) square and are representative of the display hardware configurations in current and proposed airborne weather-radar systems.

The primary pilot task for this study was to maintain a specified spacing interval behind a cockpit-displayed lead aircraft while conducting a simulated approach. A secondary pilot task was monitoring the additional surrounding traffic to insure adequate separation. Each of four pilots flew 20 approaches into a simulated Denver-Stapleton environment (fig. 2). Data were taken in the form of tracking-performance measurements and pilot questionnaires.

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RESEARCH SYSTEM

General Description

This study employed a fixed-base simulator configured as a two-engine, conventionally equipped transport aircraft (fig. 1). It should be noted that, although the simulator cockpit had four throttle controls, these controls were mechanically pinned together in pairs to represent the two-engine configuration. The host computer for this simulation was a Control Data CYBER 175 computer system, which contained the aircraft dynamics, navigation, and flight direction algorithms. The simulated aircraft dynamics modeled were those of a Boeing 737 and included nonlinear aerodynamic data and atmospheric effects. Conventional navigation instruments, which included horizontal situation indicators, flight director, and distance measuring equipment (DME), were provided in the cockpit. Normal terminal-area navigation procedures were used throughout the test. Neither autopilot nor automatic flight-control system was provided to the pilot. In addition, no attempt was made to duplicate any specific aircraft cockpit configuration or control-wheel-force feel characteristics.

Traffic Generation Scheme

The displayed traffic was generated from data previously recorded using the Langley Real-Time Simulation System. Specifically, the traffic data were created by using a piloted simulation capability, wherein flights were made along each of the routes that corresponded to the airway structure prescribed by the test scenarios. These individual flights were recorded and then merged into a set of data that was position and time correlated. The output of these merged data was the representation of numerous airplanes following several flight paths and landing with a nominal separation of 3 n.mi. at the runway threshold. This traffic-generation technique was developed for use in the study described in reference 1.

CDTI DISPLAY

General

The display used as the CDTI for this study was an 875-raster-line, monochromatic, cathode-ray tube, which could provide higher resolution than most weather-radar CRT's. The tube measured 25.4 cm (10 in.) across the diagonal and was located behind the throttle quadrant, which is the normal location for a weather-radar display on many aircraft (fig. 1). This CRT was driven by an Adage Graphics System,[1] which in turn received data from the host computer. In order to obtain the display sizes for this study, five opaque masks were used to reduce the physical display size of the CRT. This resulted in five displays with the following dimensions:

Height, cm (in.)	Width, cm (in.)
16.51 (6.5)	16.51 (6.5)
12.70 (5.0)	10.16 (4.0)
10.16 (4.0)	10.16 (4.0)
7.62 (3.0)	10.16 (4.0)
10.16 (4.0) diameter (circular)	

The general format for the CDTI was a "track-up" display with a fixed-position, own-ship symbol that was centered laterally on the display and was located longitudinally such that two-thirds of the longitudinal distance was always ahead of the own-ship symbol. The CDTI included a moving map which appeared to have continuous motion relative to the own-ship symbol and which showed the nominal ground path for the ship. This path was an electronic representation of the ILS runway 35R approach to the Denver-Stapleton airport. (The actual published approach is shown in fig. 2, and fig. 3 is an illustration of the CDTI representation of the initial portion of the approach.)

Six map scales, ranging from 0.4 to 12.6 n.mi./cm (1.0 to 32.0 n.mi./in.) were available to, and controllable by, the evaluation pilots. These six map scales are as follow:

Scale number	n.mi./cm	n.mi./in.
1	0.4	1.0
2	.8	2.0
3	1.6	4.0
4	3.2	8.0
5	6.3	16.0
6	12.6	32.0

[1]Adage Graphics System: Registered trademark of Adage, Inc.

Used in conjunction with the own-ship symbol was a lubber line, which began at the own-ship symbol and was projected directly ahead to a scaled length equivalent to 5 n.mi. (With the smallest map scale factor selected, the lubber line only extended to 3 n.mi., since at greater ranges, the 5-n.mi. end of the lubber line would be physically off the display.) In addition, range arcs were displayed on the lubber line at scaled ranges of 3 and 5 n.mi. (which were the prescribed spacing intervals for the test) in a manner that the arcs were bisected by the lubber line.

Figures 3 and 4 are representative of the general CDTI format used in this study.

Traffic Symbology

As with the moving map, the traffic aircraft symbology moved relative to the own-ship symbol. Unlike the map, however, the traffic symbology data were updated at 4-sec intervals to simulate data obtained from a terminal-area radar system. This updating interval gave the traffic symbology the appearance of being fixed to the moving map between updates and then "leaping" to its new position at the update.

The traffic symbology was obtained from the work of reference 2 and explicitly identified the traffic's altitude relative to own-ship. Traffic within an altitude band of ±150 m (500 ft) was defined to be "at" own-ship altitude. In addition, the traffic symbology included a trend vector, past position indicators, and an aircraft data block (fig. 5). The trend vector was a function of aircraft heading and ground speed and was an estimate of where the aircraft would be in 60 sec. The position history depicted three previous aircraft positions (at every other update; 8-sec intervals). An aircraft data-block option, selectable by the subject pilot from the cockpit, caused the data blocks for all the displayed aircraft to appear. All alphanumeric characters and the symbols were of constant sizes, regardless of the map scale used.

Traffic Scenario

Three traffic scenarios were developed for this study. Two of the scenarios involved a total of 13 aircraft, and the third involved 15. Each of the scenarios contained aircraft that were taking off, landing, and flying over the terminal area at high altitudes. Aircraft taking off and landing utilized runways 35L (left) and 35R (right) in a parallel, but not simultaneous, operational manner. The flight path of the aircraft taking off simulated the flight of the published Standard Instrument Departure (SID) procedures for the Stapleton-International Airport, Denver, Colorado. The landing aircraft simulated either the published instrument approach or radar vectoring to the final approach course.

In each of the scenarios, the initial position for the lead aircraft was the Kiowa VORTAC (IOC), with a heading of 253°, a speed of 250 knots, and an altitude of 4267 m (14 000 ft). The published approach was flown by this aircraft to runway 35R (fig. 2). The following aircraft in the landing sequence

was always own-ship, with an initial position 5 n.mi. behind the lead aircraft, at the same heading, airspeed, and altitude. All of the scenarios were designed to provide a minimum spacing interval of 3 n.mi. between sequential aircraft at the runway threshold.

Pilot Task

Eighty simulated instrument approaches were flown by four NASA research pilots, with each pilot flying four simulator sessions consisting of five approaches. The first approach for each session was allocated for pilot refamiliarization and used the largest (16.51 × 16.51 cm) mask size. The data from each of these initial runs, while recorded, were not used in the comparative analysis of display size. The largest mask was also used on the last approach for each session. It was this later set of data that was used to obtain the comparative results for this mask size. This testing sequence was chosen to give the pilots a basis for their subjective analysis during each test period. Given in table I is the sequence in which the mask sizes were evaluated by each pilot. Both qualitative and quantitative data were taken during the evaluation; the qualitative data in the form of pilot questionnaires (appendix A) and comments and the quantitative data in the form of spacing interval parameters.

The pilot's operational task was to establish and maintain a prescribed spacing interval behind the lead aircraft while executing an instrument approach and to maintain positive separation from other traffic in the terminal area. The simulated approach profile is shown in figure 2, and the spacing interval was established using information from the CDTI display. In "flying" the approach, the pilots were preinstructed to maintain the initial 5-n.mi. interval and to descend to an altitude of 10 000 ft (3648 m) at his discretion. At a distance of 20 n.mi. outward bound from the Kiowa VORTAC (as indicated on the cockpit DME), the pilot's task was to make a right turn, intercept the runway-35R localizer and reduce his spacing interval to 3 n.mi. The task ended when own-ship crossed the middle marker.

An additional pilot task was to monitor the display for potential traffic conflicts, even though no positive conflicts were programmed into the traffic scenarios. The test subjects had not been told that they were working with conflict-free scenarios, but rather had been preinstructed to be alert for conflicts.

In performing these experiments, the test engineer functioned as a pseudo first officer and performed such manual tasks as flap and landing gear actuation plus radio tuning in accordance with the "call-out" by the test subject. During these tests, the test engineer did not assist the test subject in controlling the simulated aircraft, monitoring the traffic display, or performing any decision-making process.

RESULTS AND DISCUSSION

Display Factors

Map scale.- Throughout these tests, the test subjects consistently used the smallest scale factor (greatest position resolution) that would keep the lead aircraft within the viewing area of the CDTI display (e.g., with the 7.62-cm × 10.16-cm (3.0-in. × 4.0-in.) mask and the 0.8-n.mi./cm (2.0 n.mi./in.) scale, the furthest the pilot could "see" ahead of own-ship was 4 n.mi.). The data points shown in figures 6 and 7 indicate the percentage of time that a specific map scale (plotted on the ordinate) was used as a function of the display height (plotted on the abscissa). It should be noted that display height was used as a primary variable in the data analysis, since this was the critical display dimension for the self-spacing task. The 5-n.mi. and 3-n.mi. boundaries shown in these two figures, respectively, define the lower map-scale limits that the test subjects could use and still observe the lead aircraft. The only time the test subjects used the larger map-scale factors was when they needed to monitor the traffic situation for potential conflicts. In order to accomplish this monitoring function, the test subjects would select larger map-scale factors and, thus, update their situational awareness. These larger map-scale factors were selected at 1- to 2-min intervals and for periods usually less than 10 sec.

This result is consistent with a similar result found in the flight study reported in reference 3. In that flight study, the test subjects generally preferred the smaller map-scale factors, except for when they "periodically selected the largest scale factor to obtain a strategic view of the traffic situation."

Data blocks.- The traffic data blocks (as shown in fig. 5) contained call-sign, altitude (above mean sea level), and ground-speed information. Throughout these tests, the test subjects constantly kept the data-block information on the display, even though they were provided with an option to delete the data blocks from the display. The primary reason, as expressed by the test subjects, for continuously displaying the data blocks was that they needed the traffic ground-speed information for both establishing a closure rate to obtain the prescribed spacing interval and, once obtained, to maintain the interval by matching own-ship ground speed to that of the lead aircraft. Thus, it was found from this experiment that target ground-speed information is an important data-block element for the self-spacing task.

This result is somewhat different from the corresponding result obtained in a previous flight study (ref. 3). In that flight study, the data-block information was used primarily for conflict resolution, and the primary information element used was altitude. However, it is believed that these are not contradictory findings because of the differences in the primary tasks. In the flight study, merging was the primary operational task, followed by a very short (1 to 2 n.mi.) spacing task. In the simulation study, the self-spacing task was continuous over two, consecutive, 20-n.mi. segments. This leads to the conclusion that the relative importance of the individual element within a data block is directly related to the specific operational task.

Traffic update interval.- As previously indicated, the relative position of the surrounding traffic was updated at 4-sec intervals. One consistent comment from one of the test subjects was that this update rate, coupled with the physical location of the traffic display, caused him to "spend too much time away from his primary flight displays." Furthermore, this was one of the NASA research pilots who served as a test subject on the previous flight study (ref. 3) and had not noted update rate/location as a problem. Also in that flight study, the traffic display was located on the electronic horizontal situation indicator (EHSI), which was located in the primary scan pattern of the test subject, as contrasted with the simulation study. An additional contributor was the operational task. As previously indicated, the operational task for the flight study was basically a merge task followed by a very brief spacing task, as compared with a prolonged spacing task in the simulation study. The primary conclusion that can be drawn from this comment is that there may be a relationship between display update rate, display location, and the operational task.

Display clutter.- In the previous flight study (ref. 3), display clutter was found to be a major problem. In this simulation study, display clutter was less of a problem, primarily because there were fewer target aircraft on the CDTI display. This relative decrease in the number of target aircraft was caused by the test subject's desire to have the highest position resolution, which resulted in the use of smaller scale factors. However, when the test subjects switched to larger scale factors to monitor the strategic traffic situation, the display did become severely cluttered, with many of the data blocks becoming unreadable, as one overlayed another. From a theoretical viewpoint, the display clutter problem should increase with a reduction in display size because, for a given task, the same information content is placed in a smaller display area.

Workload and Spacing Performance

In partial-workload simulation studies it is impossible to simulate the full-workload conditions associated with a "real-world" operational task. In this study the pilot was not required to communicate with an air traffic controller nor was he required to perform normal procedural checks (before landing checklist, etc.). However, for this simulation study, the subject pilot's workload was elevated above a normal partial-workload level by requiring him to function as a single pilot; that is, he was required to exercise total manual control of the simulated aircraft without using any autopilot features, was required to perform all of the traffic display monitoring, and was further required to perform all decision-making functions. It is believed, therefore, that this simulation task tended to elevate the test subject workload equal to or above that required in the "real world."

Display size impact on task difficulty.- As a part of the pilot's questionnaire for this study, the test subjects were asked to mark, on a bar graph, their rating of the task difficulty of the self-spacing and traffic-monitoring tasks for each display size. The results of these ratings have been combined for all pilots and the distributions normalized to percentage values, which are

shown in figure 8. One primary result of these ratings was that even the smallest display size (7.62 cm × 10.16 cm (3.0 in. × 4.0 in.)) was judged to be usable, though relatively more difficult, to the test subjects for performing the specified tasks. This result is contrary to an initial hypothesis that the smallest display size would be too small to provide the position resolution needed to perform a spacing task, and it is significant that this hypothesis was found to be untrue.

In further reviewing the combined data shown in figure 8, the test subjects indicated a preference for the larger displays. As suggested by the original hypothesis, this was an expected result and probably can be attributed to the increased position resolution resulting from an increased display size. Another factor which may have contributed to this trend was that the larger display sizes allowed the test subjects to select smaller map-scale factors, which in turn reduced the apparent display clutter.

Task effect on workload.- During this study, the test subjects commented that a significant part of this workload could be attributed to the precision speed control required by the task. Specifically, they indicated that a high level of concentration was needed to make the precision speed adjustments required to obtain and maintain the spacing intervals prescribed in the tests. In conducting these tests, the test subjects were told that their spacing precision (their ability to accurately maintain the prescribed spacing interval) would be recorded and used as a performance measure. This precision control element of the simulation task may not represent a realistic requirement in a "real-world" operating environment where high spacing precision would not be required for prolonged periods of time.

Spacing performance.- The spacing performance results for the various display heights are shown in figures 9 to 12. (There was no statistical difference found between the 10.16-cm (4.0-in.) square mask and the 10.16-cm (4.0-in.) circular mask at the 90-percent confidence interval; thus, these two sets of data were combined.) In these figures, all of the data obtained for a particular display height were merged together in order to analyze the spacing interval as a function of time. These figures, then, are plots of the spacing interval's mean and standard deviation versus time for each of the display heights. A comparison of the mean results (figs. 9 to 12) indicates that the mean spacing values exhibit the same profile trends, irrespective of display size. For example, the 3-n.mi. spacing interval (figs. 9 to 12) consistently approached $3\frac{1}{4}$ n.mi. for all of the display heights utilized.

It should be noted that this $3\frac{1}{4}$-n.mi. spacing interval reflected a conservative result, considering that a 3-n.mi. interval was the specified interval. These longer-than-specified spacing intervals (which were also noted in the 5-n.mi. spacing segment) may have been caused by the traffic information update process. Between target updates, the targets are fixed with respect to the moving map, which causes a reduction in the perceived spacing interval for an in-trail situation. Other factors, such as the pilot's inherent desire not to overshoot the prescribed spacing interval, may have also contributed to this bias value.

The standard deviation envelopes, also shown in figures 9 to 12, indicate a consistent increase in the standard deviation values as the display size is reduced. By further examining the 3-n.mi. spacing interval, it can be seen that the increase in the standard deviation envelopes (which implies a decrease in performance) appears to be greatest for the incremental change from the 12.70-cm (5.0-in.) to the 10.16-cm (4.0-in.) display height and may indicate a range of display heights (and scale factors) for which a discrete change in spacing performance would be seen.

The mean and standard deviation values for the 5-n.mi. and 3-n.mi. segments were further analyzed as a function of display height. In this analysis, the data were partitioned by the prescribed spacing-interval parameter, with the analysis for the 5-n.mi. interval starting 180 sec after the data run was initiated and terminating just prior to initiation of the closure to the 3-n.mi. spacing interval. For the 3-n.mi. interval, the data analysis was started at the completion of the closure maneuver and terminated when the lead aircraft landed. Mean spacing values were then obtained by combining all of the performance data for each combination of spacing interval and display height. These mean spacing values, together with their respective standard deviations, are given in appendix B and are plotted in figure 13. In all instances, the mean values were always greater than the prescribed 5- and 3-n.mi. spacing.

The standard deviation values, taken from appendix B, are plotted in figure 14. For the 3-n.mi. spacing interval (fig. 14(b)), the data appear to fall on two separate and distinct curves, depending on the scale factors used. Extending this analysis to the 5-n.mi. spacing, a linear regression computation, applied to the 0.8-n.mi./cm (2.0 n.mi./in.) scale factor data, produced a coefficient of determination of 1.000 (indicative of a near perfect linear fit). Both instances indicate that standard deviation decreases (performance improves) as the display height increases, and it is concluded from this analysis that pilot performance is significantly affected by the scale factors used, which are a function of the display height and the spacing interval. That is, there exists an interrelationship between pilot tracking performance and the spacing interval, the display height, and the map-scale factors.

CONCLUSIONS

A flight simulation study was conducted to determine the effect of display size on the pilot's ability to utilize a Cockpit Display of Traffic Information (CDTI) for a self-spacing task. Based on these results the following conclusions are drawn:

1. Pilot subjective data indicated that, from a workload viewpoint, even the smallest display size was usable for performing the self-spacing task.

2. According to pilot commentary, the traffic data update rate affects the amount of time that the pilot's visual attention is away from his primary flight instruments when the traffic information is presented on a display that is outside the pilot's primary visual scan pattern.

3. A significant portion of the workload associated with the self-spacing task was attributed to the precision speed control required to maintain the prescribed spacing intervals.

4. The mean spacing values exhibited the same trends irrespective of display size, but the standard deviation of the spacing intervals decreased (performance improves) as the display heights increased; thus, display size appears to have a significant effect on pilot performance.

5. For the self-spacing task, the subject pilots consistently used the smallest map-scale factor (highest position resolution) that would keep the lead aircraft within the viewing area of the CDTI. Therefore, the specific map scale used was a function of the traffic spacing interval and the height of the display.

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APPENDIX A

PILOT QUESTIONNAIRE

The questions that were in the pilot questionnaire are given in this appendix. The appendix is not intended to be a duplicate of the questionnaire; the questions are the same but the space allowed for answers has been deleted. The display size questions were repeated for each simulation session for each display mask employed.

GENERAL QUESTIONS

1. What features of the display do you consider most desirable?

2. What features of the display do you consider least desirable?

3. Comment on the quantity and quality of the displayed information:

   (a) Clutter

   (b) Contrast, resolution, and brightness

   (c) Symbol size

   (d) Character size

   (e) Other

4. What impact might use of color have on problems identified?

5. Do you feel that you needed more control over display content?

6. Given a solution to the wake vortex problem, would you be willing to accept reduced separation for this test configuration? If yes, by how much?

7. Did you feel that the traffic information affected your traditional piloting task? If so, did it degrade or enhance the task? Elaborate.

8. To what extent did workload affect traffic monitoring?

DISPLAY SIZE QUESTIONS

1. Which scale factor(s) did you prefer and why?

2. Were the map coverage and situation resolution satisfactory at the preferred scale factor(s)?

3. With this size display, how difficult was the tracking task at the scale factor(s) used?

easy | | | | | | | | | | | hard

4. With this size display, how difficult was the monitoring task at the scale factor(s) used?

easy | | | | | | | | | | | hard

5. Did your interpretation of the display create, at any time, a feeling of uncertainty with respect to need for evasive action?

6. How often did you check the traffic information?

7. Did you at any time perceive the need for an alerting device to direct your attention to the traffic information? If so, what type of device/technique would you prefer?

APPENDIX B

STATISTICAL ANALYSIS

An analysis of the variance for a two-factor experiment with replication was applied to the spacing-interval data obtained from this study. The elements of consideration in this analysis were pilot effects and display-height effects. The following results were obtained: display-height effects for the 5-n.mi. prescribed spacing interval was found to be significant at the 95-percent confidence interval; display-height effects for the 3-n.mi., prescribed spacing interval was found to be significant at the 99-percent confidence interval; and pilot effects were found not to be significant at the 90-percent confidence interval for either spacing interval.

Also computed in the statistical analysis were the mean and the standard deviation values for both prescribed spacing intervals as functions of display height. The results of this computation are as follows:

5-n.mi prescribed spacing

Display height, cm (in.)	Mean, n.mi.	Standard deviation, n.mi.
16.51 (6.5)	5.291	0.1898
12.70 (5.0)	5.226	.2104
10.16 (4.0)	5.274	.2296
7.62 (3.0)	5.262	.2639

3-n.mi. prescribed spacing

Display height, cm (in.)	Mean, n.mi.	Standard deviation, n.mi.
16.51 (6.5)	3.197	0.314
12.70 (5.0)	3.077	.1643
10.16 (4.0)	3.077	.2668
7.62 (3.0)	3.165	.2825

Additionally, frequency histograms are shown in figures 15 and 16 for both the 5-n.mi. and 3-n.mi. prescribed spacing intervals, respectively. These figures graphically illustrate the increase in the spacing dispersion (and standard deviation) as the display height is reduced.

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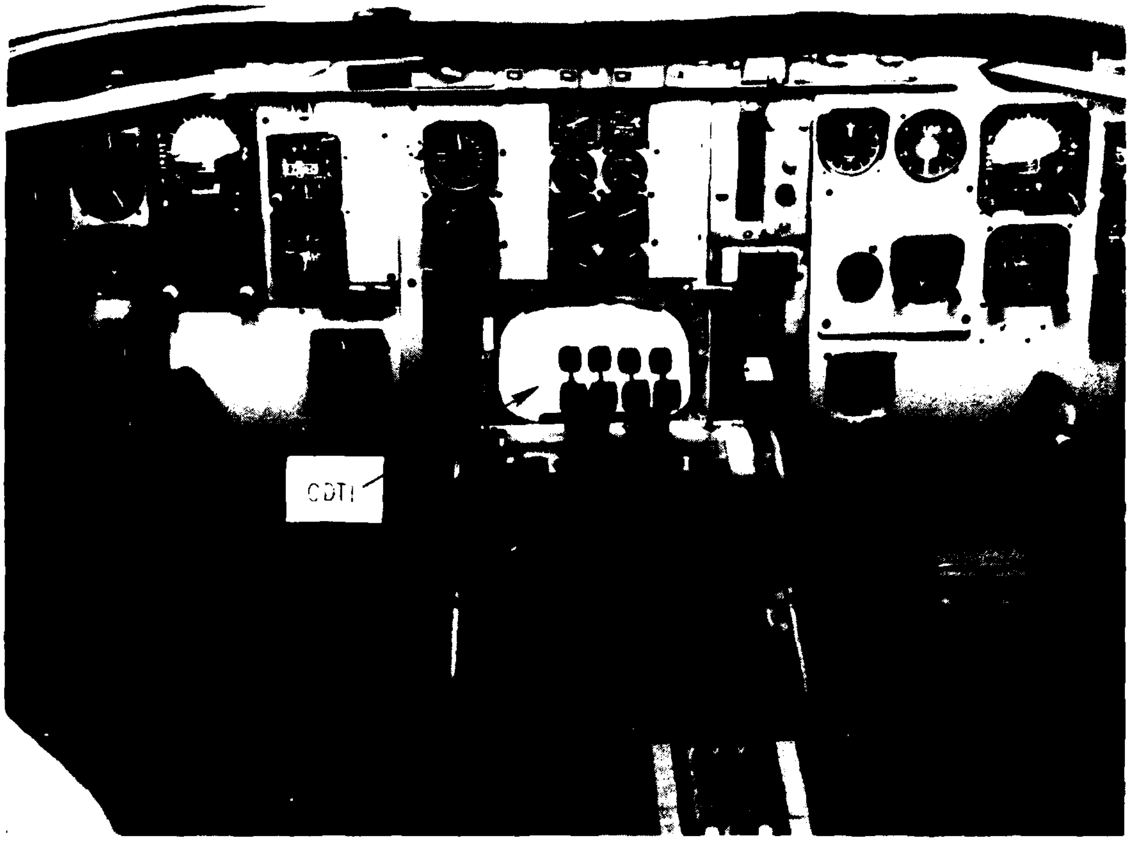
3. Abbott, Terence S.; Moen, Gene C.; Person, Lee H., Jr.; Keyser, Gerald L., Jr.; Yenni, Kenneth R.; and Garren, John F., Jr.: Flight Investigation of Cockpit-Displayed Traffic Information Utilizing Coded Symbology in an Advanced Operational Environment. NASA TP-1684, AVRADCOM TR 80-B-4, 1980.

TABLE I.- TEST SEQUENCE

Pilot 1		Pilot 2		Pilot 3		Pilot 4	
Run number	Mask number	Run number	Mask number	Run number	Mask number	Run number	Mask number
1	1	6	1	26	1	21	1
2	5	7	3	27	2	22	4
3	5	8	3	28	2	23	4
4	5	9	3	29	2	24	4
5	1	10	1	30	1	25	1
16	1	11	1	51	1	31	1
17	3	12	2	52	4	32	5
18	3	13	2	53	4	33	5
19	3	14	2	54	4	34	5
20	1	15	1	55	1	35	1
46	1	36	1	71	1	41	1
47	2	37	4	72	5	42	3
48	2	38	4	73	5	43	3
49	2	39	4	74	5	44	3
50	1	40	1	75	1	45	1
56	1	66	1	76	1	61	1
57	4	67	5	77	3	62	2
58	4	68	5	78	3	63	2
59	4	69	5	79	3	64	2
60	1	70	1	80	1	65	1

Mask number	Display size, height × width
1	16.51 cm × 16.51 cm (6.5 in. × 6.5 in.)
2	12.70 cm × 10.16 cm (5.0 in. × 4.0 in.)
3	10.16 cm × 10.16 cm (4.0 in. × 4.0 in.)
4	10.16 cm diameter (4.0 in.)
5	7.62 cm × 10.16 cm (3.0 in. × 4.0 in.)



L-80-7799.1

Figure 1.- Simulator cockpit with Cockpit Display of Traffic Information (CDTI).

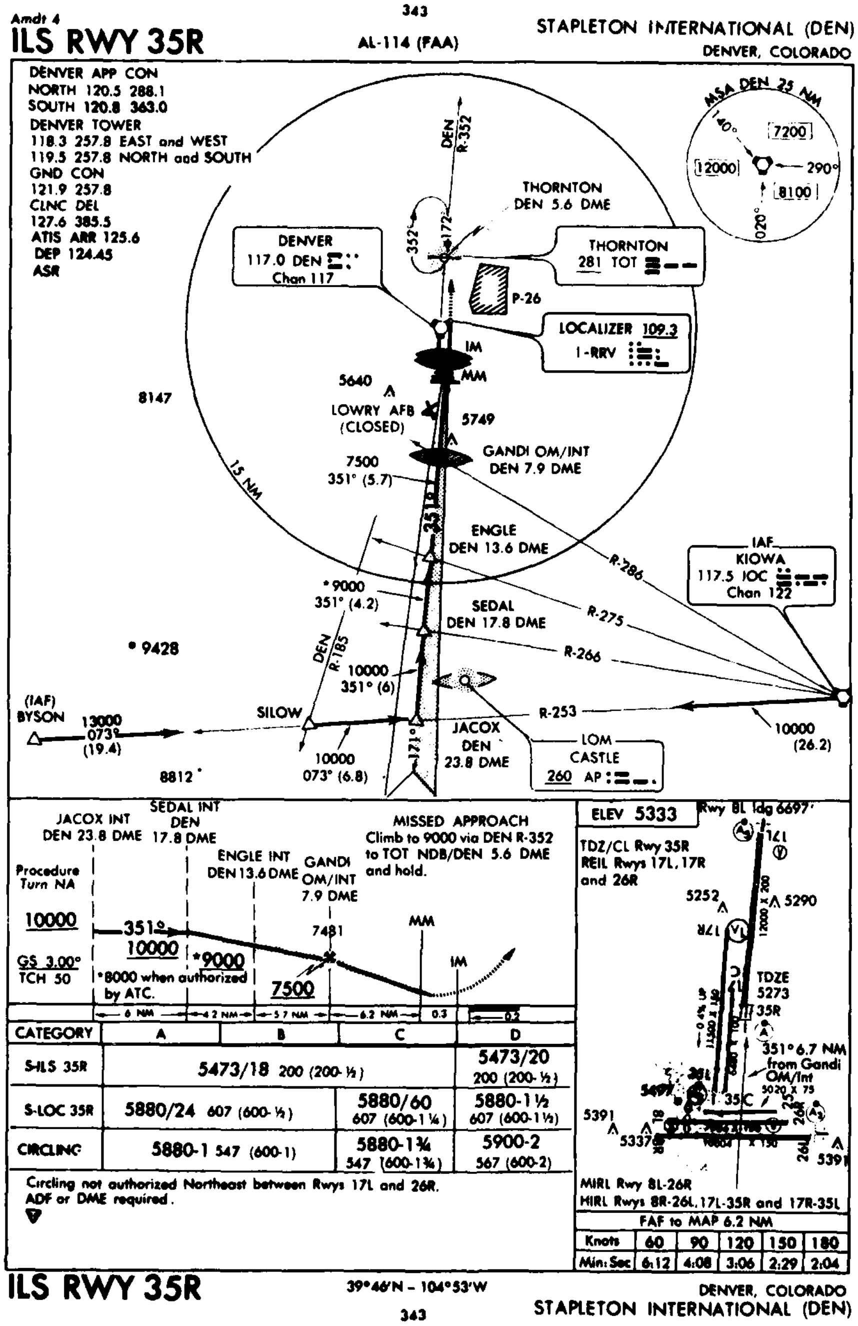


Figure 2.- Approach chart.

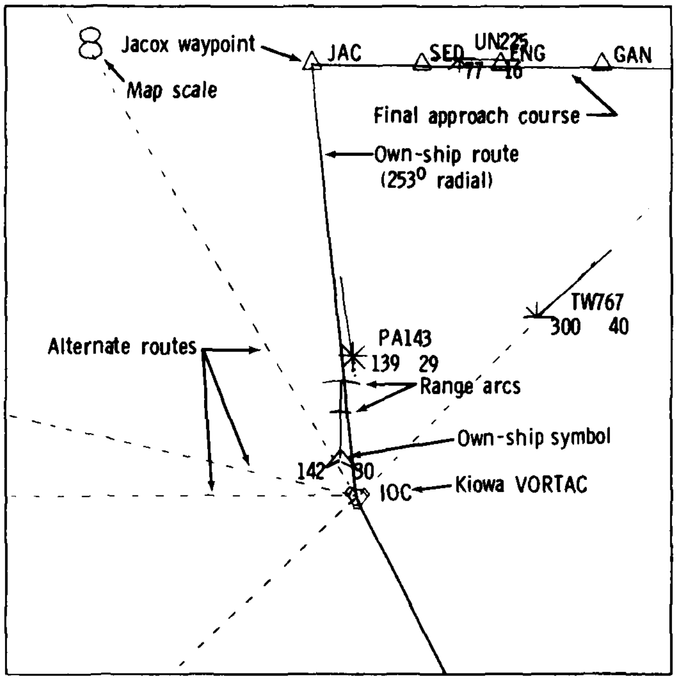


Figure 3.- CDTI format, map scale 8.

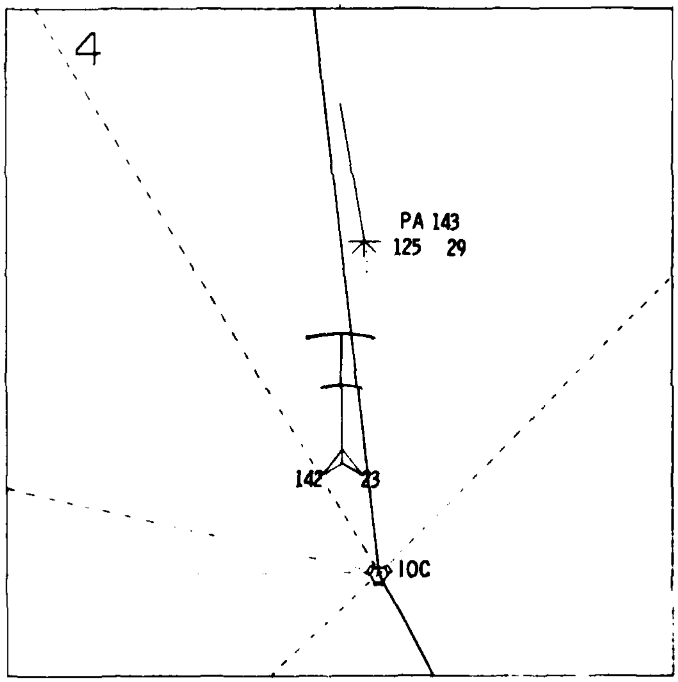
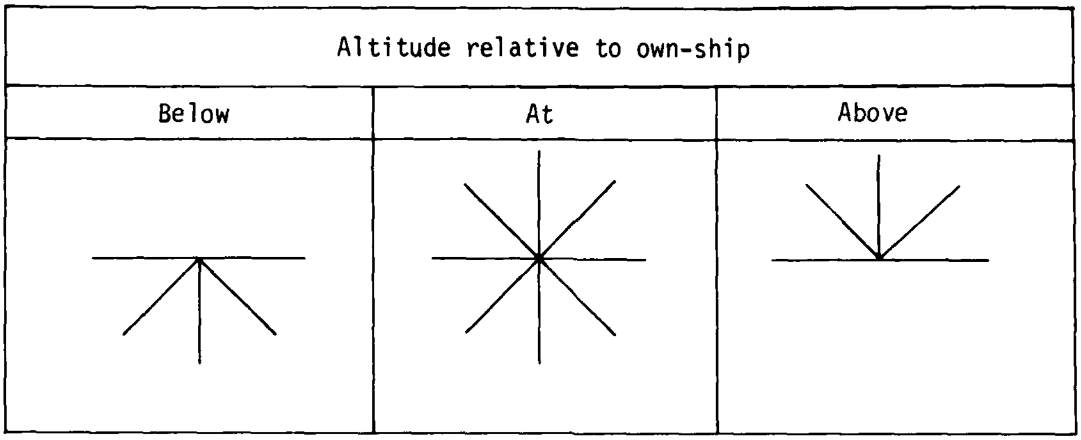
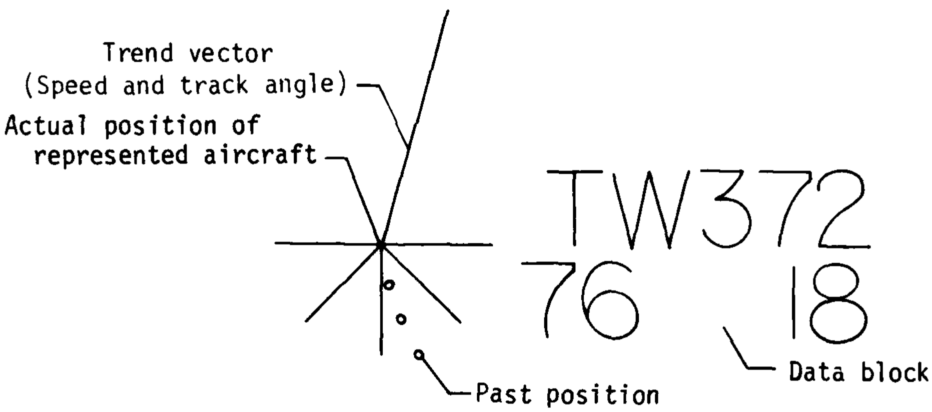


Figure 4.- CDTI format, map scale 4.





Data-block format	
Identifier	
Altitude/100	Speed/10

Figure 5.- Traffic symbology.

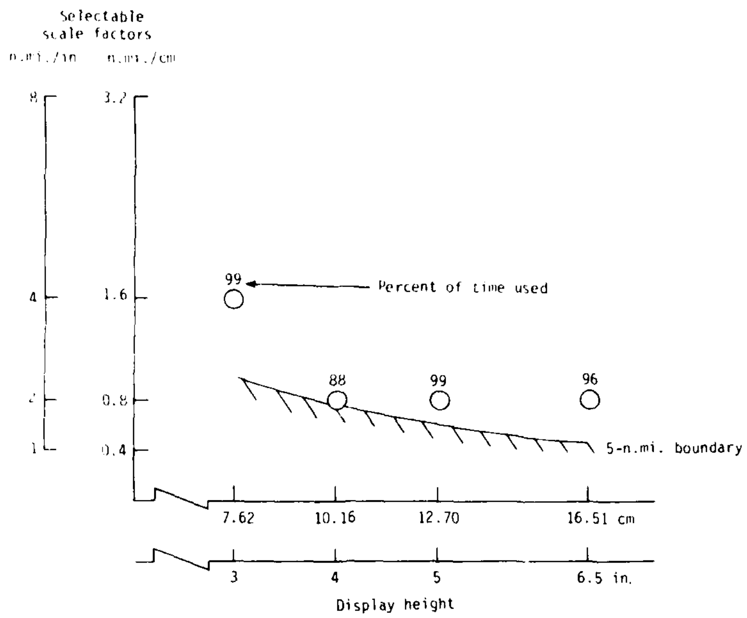


Figure 6.- Preferred map-scale factors for 5-n.mi. self-spacing task.

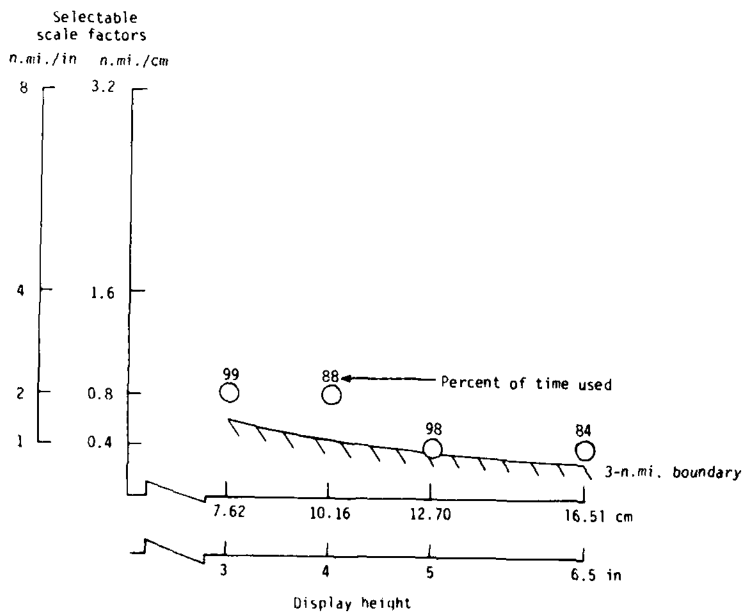


Figure 7.- Preferred map-scale factors for 3-n.mi. self-spacing task.

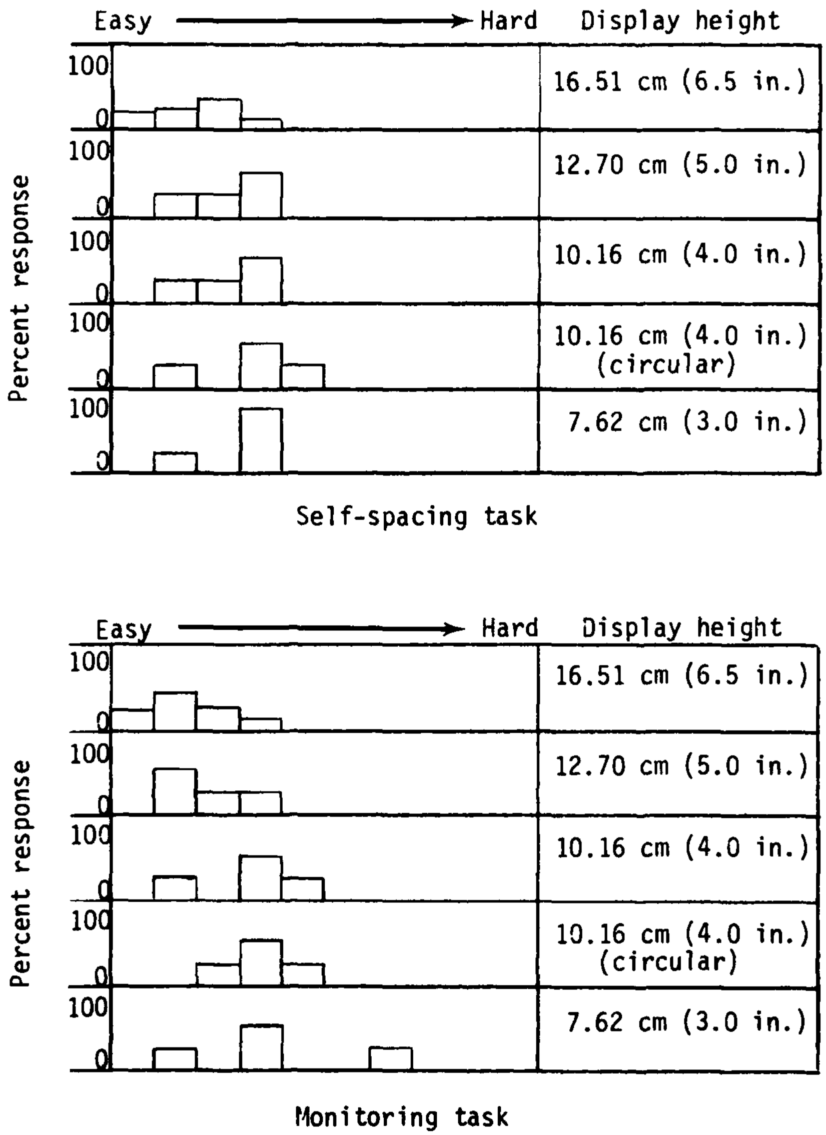


Figure 8.- Task difficulty as function of display height. (Data extracted from pilot questionnaires.)

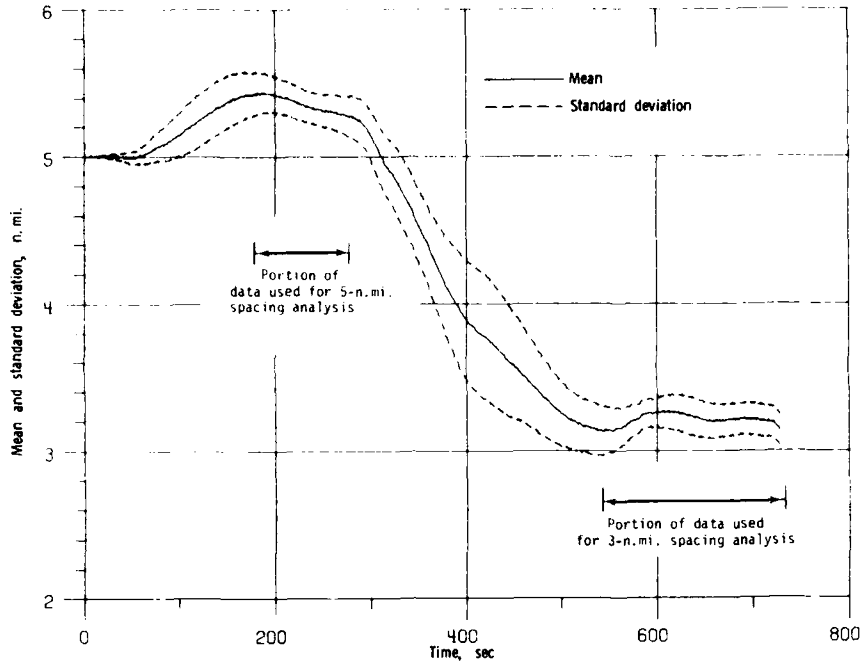


Figure 9.- Mean and standard deviation for 16.51-cm (6.5-in.) display.

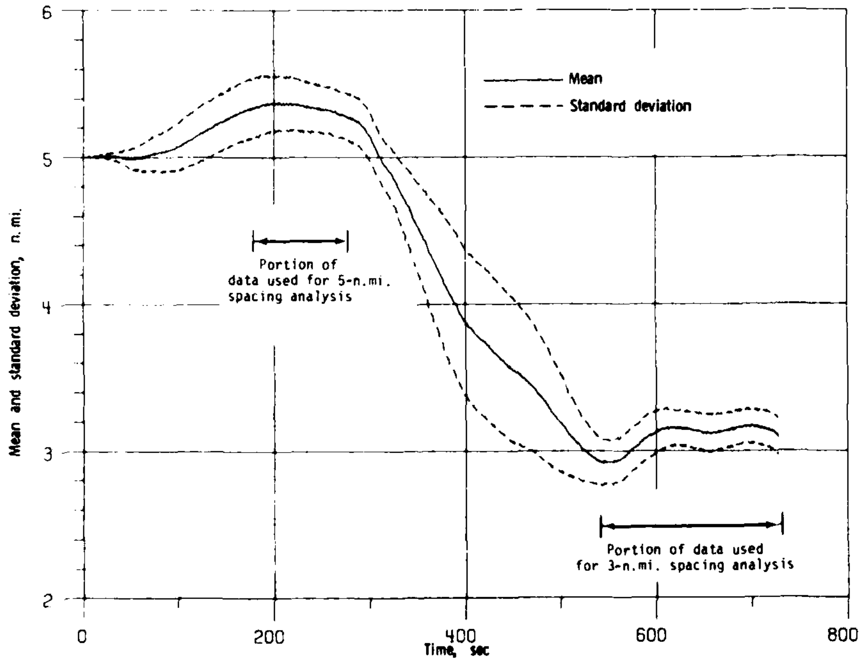


Figure 10.- Mean and standard deviation for 12.7-cm (5.0-in.) display.

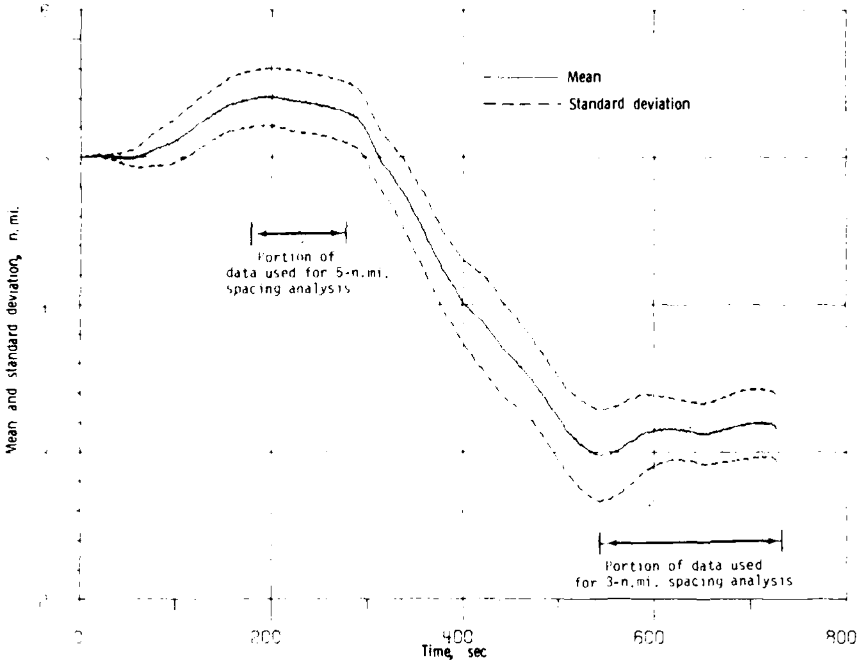


Figure 11.- Mean and standard deviation for 10.16-cm (4.0-in.) display.

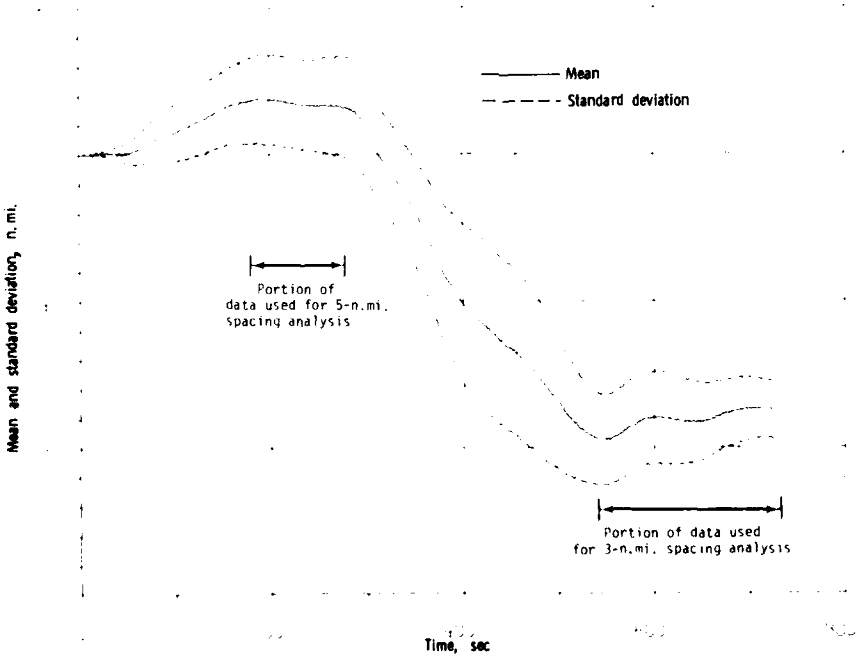


Figure 12.- Mean and standard deviation for 7.62-cm (3.0-in.) display.

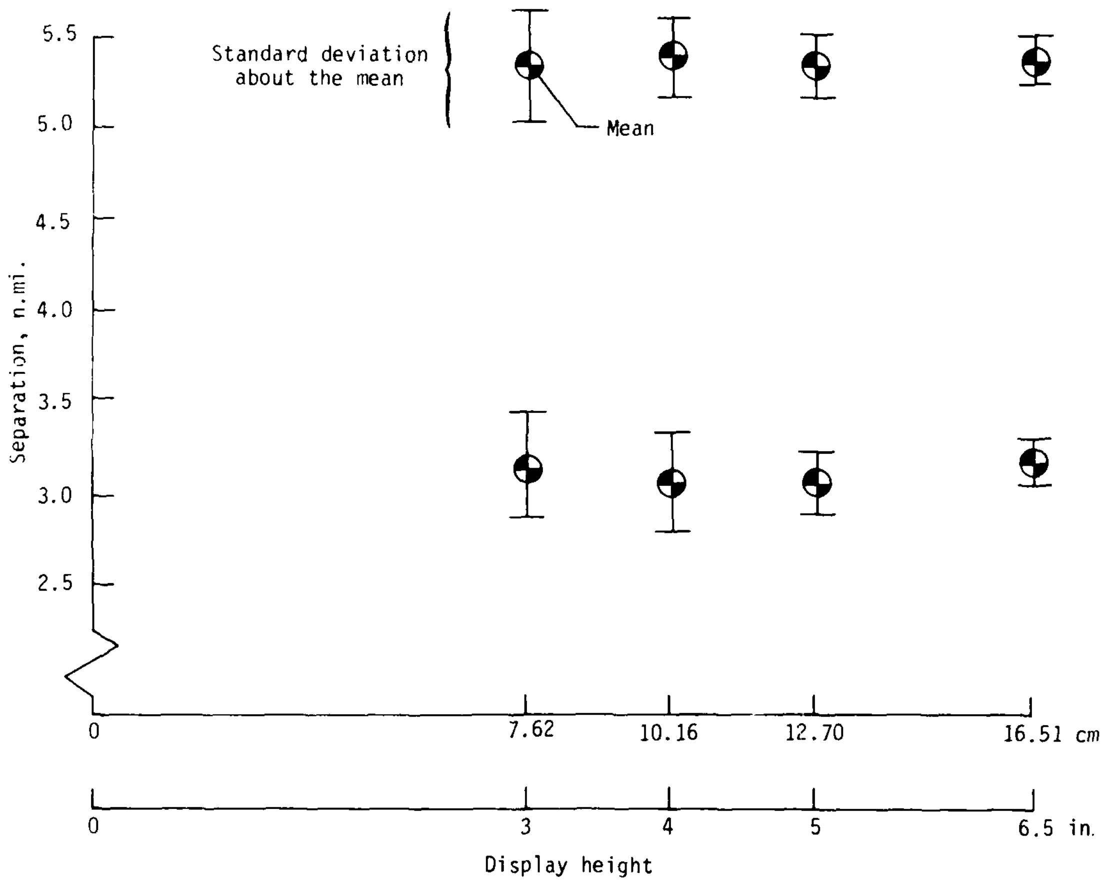
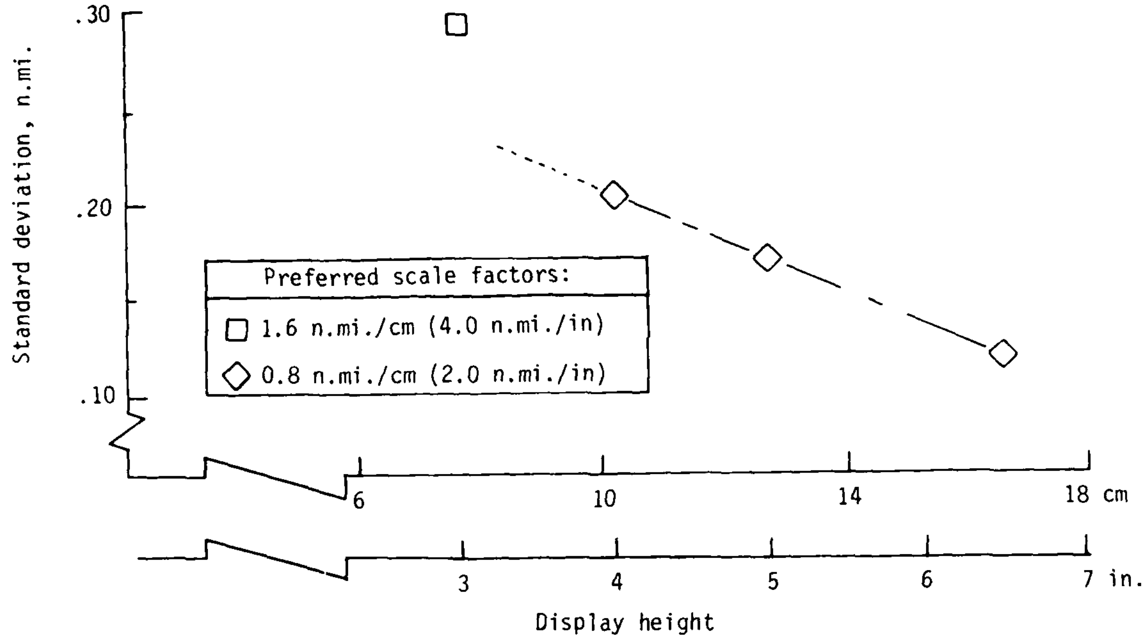
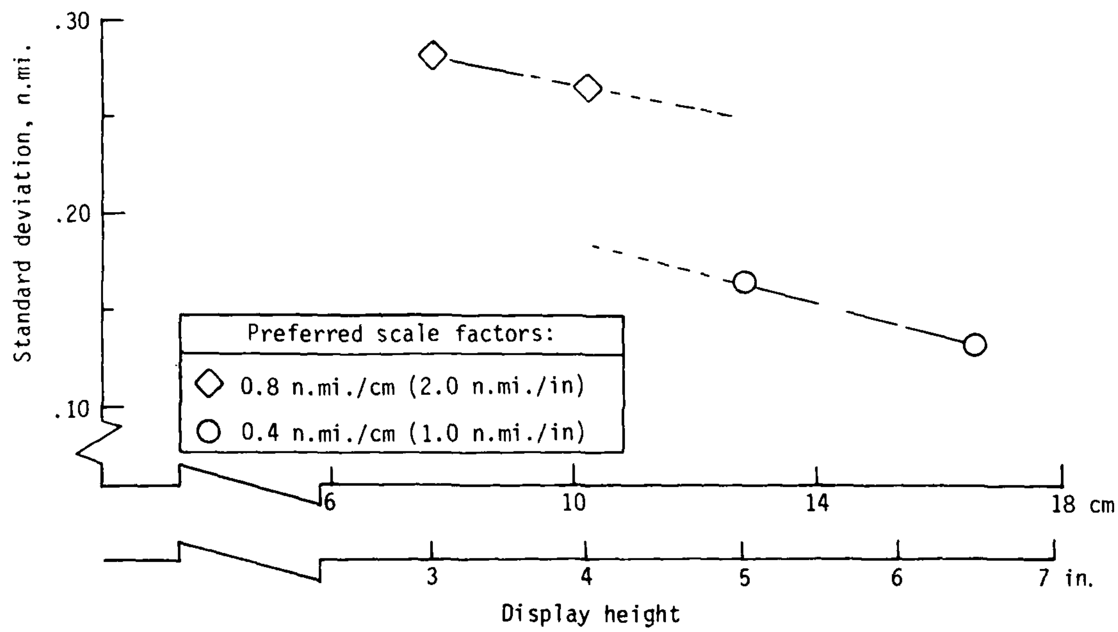


Figure 13.- Means and standard deviations for prescribed spacing intervals.

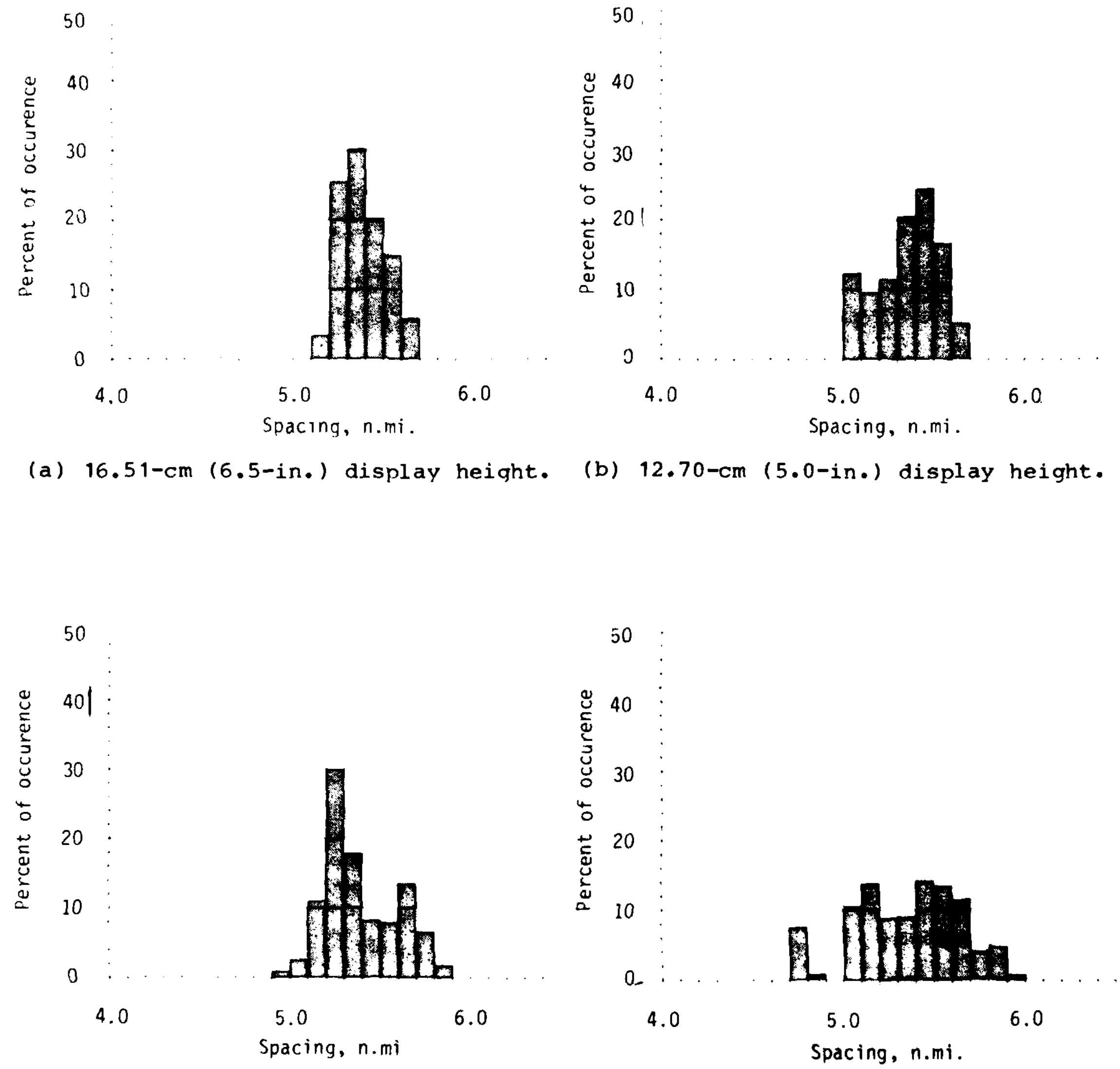


(a) Five-nautical-mile segment.



(b) Three-nautical-mile segment.

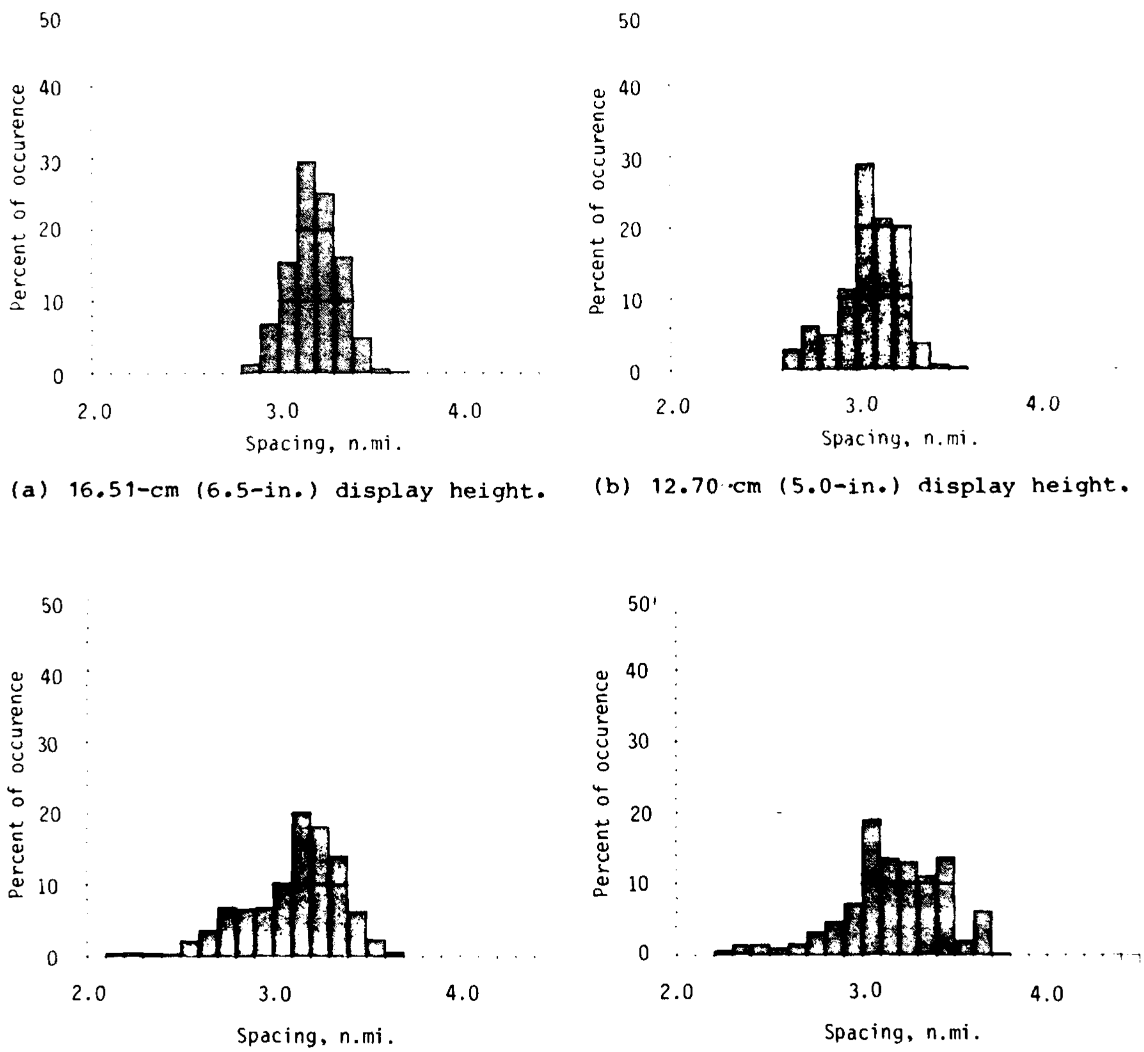
Figure 14.- Segment standard deviation vs. display height.



(a) 16.51-cm (6.5-in.) display height. (b) 12.70-cm (5.0-in.) display height.

(c) 10.16-cm (4.0-in.) display height. (d) 7.62-cm (3.0-in.) display height.

Figure 15.- Frequency histogram of spacing interval for 5-n.mi. prescribed interval.



(a) 16.51-cm (6.5-in.) display height.

(b) 12.70-cm (5.0-in.) display height.

(c) 10.16-cm (4.0-in.) display height.

(d) 7.62-cm (3.0-in.) display height.

Figure 16.- Frequency histogram of spacing interval for 3-n.mi. prescribed interval.

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16. Abstract

Applications of Cockpit Display of Traffic Information (CDTI) in the operation of current, conventionally equipped transport aircraft were studied. Since flight decks of the current transport-aircraft fleet probably will not be reconfigured to accommodate a special display dedicated to this purpose, the weather-radar cathode-ray tube (CRT) is the prime candidate for presenting CDTI. Unique problems may result from this, since the CRT size is not optimized for CDTI applications and the CRT is not in the pilot's primary visual scan area. Our primary objective was to assess the impact of display size on the ability of pilots to utilize the traffic information to maintain a specified spacing interval behind a lead aircraft during an approach task. The five display sizes considered are representative of the display hardware configurations of airborne weather-radar systems. From a pilot's subjective workload viewpoint, even the smallest display size was usable for performing the self-spacing task. From a performance viewpoint, the mean spacing values, which are indicative of how well the pilots were able to perform the task, exhibit the same trends, irrespective of display size; however, the standard deviation of the spacing intervals decreased (performance improves) as the display size increased. Display size, therefore, does have a significant effect on pilot performance.

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